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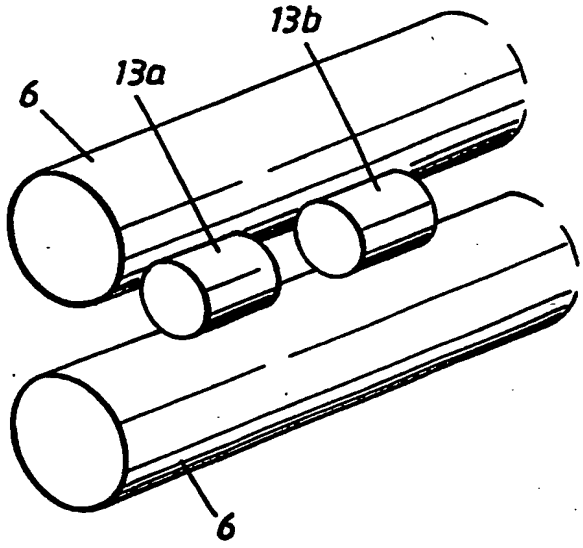
(57) Abstract

The invention relates to a rotating electric machine having a stator (1) with windings drawn through slots (5) in the stator. According to the invention the windings consist of high-voltage cable (6), a plurality of resilient bodies (13) being arranged along at least one cable lead-through (6). The bodies (13) are arranged to abut onto the cable lead-through (6) with pressure. The invention also relates to a method in the manufacture of such a machine. According to this method the stator is wound with high-voltage cable, after which a plurality of resilient bodies are inserted axially in at least one slot in a space formed between adjacent cable lead-throughs and one wall f the slot.



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ROTATING ELECTRICAL MACHINE COMPRISING HIGH-VOLTAGE WINDING AND ELASTIC BODIES SUPPORTING THE WINDING AND METHOD FOR MANUFACTURING SUCH MACHINE

The present invention relates in a first aspect to a rotating electric machine of the type described in the preamble to claim 1, e.g. synchronous machines, normal synchronous machines as well as dual-fed machines, applications in asynchronous static current converter cascades, outerpole machines and synchronous flow machines.

A second aspect of the invention relates to a method of the type described in the preamble to claim 18.

In the present application the terms "radial", "axial" and "peripheral" constitute indications of direction defined in relation to the stator of the machine unless expressly stated otherwise. The term "cable lead-through" refers in the application to each individual length of the cable extending through a slot.

The machine is intended primarily as a generator in a power station for generating electric power. The machine is intended to be used at high voltages. High voltages shall be understood here to mean electric voltages in excess of 10 kV. A typical operating range for the machine according to the invention may be 36 to 800 kV.

Similar machines have conventionally been designed for voltages in the range 6-30 kV, and 30 kV has normally been considered to be an upper limit. This usually implies that a generator is to be connected to the power network via a transformer which steps up the

voltage to the level of the power network, i.e. in the range of approximately 100-400 kV.

By using high-voltage insulated electric conductors, in the following termed cables, with solid insulation similar to that used in cables for transmitting electric power in the stator winding (e.g. XLPE cables) the voltage of the machine may be increased to such levels that it may be connected directly to the power network without an intermediate transformer. XLPE = Cross-linked polyethylene .

This concept generally implies that the slots in which the cables are placed in the stator be deeper than conventional technology (thicker insulation due to higher voltage and more turns in the winding) dictates. This entails new problems with regard to cooling, vibrations and natural frequencies in the region of the coil ends, teeth and winding.

Securing the cable in the slot is also a problem - the cable is to inserted into the slot without its outer layer being damaged. The cable is subjected to currents having a frequency of 100 Hz which cause a tendency to vibration and, besides manufacturing tolerances with regard to the outer diameter, its dimensions will also vary with variations in temperature (i.e. load variations).

Although the predominant technology when supplying current to a high-voltage network for transmission, sub-transmission and distribution, is to insert a transformer between the generator and the power network as mentioned in the introduction, it is already known to endeavour to eliminate the transformer by generating the voltage directly at the level of the network. Such

a generator is described in US-4 429 244, US-4 164 672 and US-3 743 867.

It is considered possible to manufacture coils for rotating machines with good results up to a voltage range of 10-20 kV.

Attempts at developing a generator for voltages higher than this have been in progress for some time, as is evident from "Electrical World", October 15 1932, pages 524-525, for instance. This describes how a generator designed by Parson 1929 was constructed for 33 kV. A generator in Langerbrugge, Belgium, is also described which produced a voltage of 36 kV. Although the article also speculates on the possibility of increasing the voltage levels, development of the concepts upon which these generators were based ceased. This was primarily due to deficiencies in the insulating system in which several separate layers of varnish-impregnated mica foil and paper were used.

Certain attempts at lateral thinking in the design of synchronous generators are described in an article entitled "Water-and-oil-cooled Turbogenerator TVM-300" in J. Elektrotechnika, No. 1 1970, pages 6-8 of US 4,429,244 "Stator of generator" and in Russian patent specification CCCP Patent 955369.

The water-and-oil-cooled synchronous machine described in J. Elektrotechnika is intended for voltages up to 20 kV. The article describes a new insulation system consisting of oil/paper insulation which enables the stator to be completely immersed in oil. The oil can then be used as coolant at the same time as constituting insulation. A dielectric oil-separating ring is provided at the internal surface of the core to

prevent oil in the stator from leaking out towards the rotor. The stator winding is manufactured from conductors having oval, hollow shape, provided with oil and paper insulation. The coil sides with the insulation are retained in the slots with rectangular cross section by means of wedges. Oil is used as coolant both in the hollow conductors and in cavities in the stator walls. However, such cooling systems necessitate a large number of connections for both oil and electricity at the coil ends. The thick insulation also results in increased radius of curvature of the conductors which in turn causes increased size of the coil overhang.

The above-mentioned US patent relates to the stator part of a synchronous machine comprising a magnetic core of laminated plate with trapezoid slots for the stator winding. The slots are stepped since the need for insulation of the stator winding is less in towards the rotor where the part of the winding located closest to the neutral point is situated. The stator part also includes a dielectric oil-separating cylinder nearest to the inner surface of the core. This part could increase the excitation requirements in comparison with a machine lacking this ring. The stator winding is manufactured from oil-saturated cables having the same diameter for each layer of the coil. The layers are separated from each other by means of spacers in the slots and secured with wedges. Characteristic of the winding is that it consists of two "half-windings" connected in series. One of the two half-windings is situated centrally inside an insulating sheath. The conductors of the stator winding are cooled by surrounding oil. A drawback with so much oil in the system is the risk of leakage and the extensive cleaning-up process resulting from a faulty condition.

The parts of the insulating sheath located outside the slots have a cylindrical part and a conical screening electrode whose task it is to direct the electrical field strength in the area where the cable leaves the plate.

It is evident from CCCP 955369 that in another attempt at increasing the rated voltage of a synchronous machine, the oil-cooled stator winding consists of a conductor with insulation for medium-high voltage, having the same dimension for all layers. The conductor is placed in stator slots which are in the shape of circular, radially situated openings corresponding to the cross-sectional area of the conductor and necessary space required for fixation and cooling. The various radially located layers of the winding are surrounded and fixed in insulating tubes. Insulating spacer elements fix the tubes in the stator slot. In view of the oil cooling. an inner dielectric ring is also required here to seal the oil coolant from the inner air gap. The illustrated construction shows no stepping of either insulation or stator slots. The construction shows an extremely narrow, radial waist between the various stator slots, entailing a large slot leakage flow which greatly affects the excitation requirements of the machine.

In A report from the Electric Power Research Institute, EPRI, EL-3391, from April 1984 an exposition is given of the generator concept in which a higher voltage in an electric generator is achieved with the object of connecting such a generator to a power network without intermediate transformers. The report deems such a solution profitable in its being effective and financially advantageous. The main reason that it was considered possible in 1984 to start developing

generators for direct connection to the power network was that by that time a superconducting rotor had been developed. The considerable excitation capacity of the superconducting field makes it possible to use air-gap windings with sufficient thickness to withstand the electric stresses.

By combining the construction of an excitation circuit with winding, a so-called "monolith cylinder armature", a concept in which two cylinders of conductors are enclosed in three cylinders of insulation and the whole structure is attached to an iron core without teeth, it was deemed that a rotating electric machine for high voltage could be directly connected to a power network. This solution implies that the main insulation is to be made sufficiently thick to withstand network-to-network and network-to-earth potentials. Besides it requiring a superconducting rotor, an obvious drawback with the proposed solution is that it requires a very thick insulation, thus increasing the size of the machine. The coil ends must be insulated and cooled with oil or freones in order to direct the large electric fields into the ends. The whole machine is to be hermetically enclosed to prevent the liquid dielectric medium from absorbing moisture from the atmosphere.

The present invention is related to the above-mentioned problems associated with avoiding damage to the surface of the cable upon its insertion into the stator slots and avoiding wear against the surface caused by vibration during operation. The slot through which the cable is inserted is relatively uneven or rough since in practice it is extremely difficult to control the position of the laminated plates sufficiently exactly to obtain a perfectly uniform surface. The rough

surface has sharp edges which may shave off parts of the semiconductor layer surrounding the cable. This leads to corona and break-through at operating voltage.

When the cable is placed in the slot and adequately clamped there is no risk of damage during operation. Adequate clamping implies that forces exerted (primarily radially acting current forces with double mains frequency) do not cause vibrations that cause wear on the semiconductor surface. The outer semiconductor must thus be protected against mechanical damage during operation.

During operation the cable is also subjected to thermal loading so that the XLPE material expands. The diameter of a 145 kV XLPE cable, for instance, increases by about 1.5 mm at an increase in temperature from 20 to 70°. The cable must be given the necessary Space due to thermal expansion.

Against this background the object of the present invention is to solve the problems associated with achieving a machine of the type under consideration so that the cable is not subjected to mechanical damage during winding as a result of vibrations, and which permits thermal expansion of the cable. Achieving this would enable the use of cables that do not have a mechanically protecting outer layer. In such a case the outer layer of the cable would consist of a thin semiconductor material which is sensitive to mechanical damage.

According to a first aspect of the invention this has been solved by giving a machine, of the type described in the preamble to claim 1, the special features defined in the characterizing part of this claim.

Thanks to the resilient bodies, the high-voltage cable will be clamped at certain points along its length in order to reduce vibration problems . It may then be ensured that the vibrations do not generate natural frequencies in certain critical frequency ranges. Natural frequencies of 100 Hz should particularly be avoided.

According to a preferred embodiment of the invention at least one semiconducting layer has a coefficient of thermal expansion equivalent to that of the intermediate solid insulation. Defects, cracks and the like are thus avoided upon thermal movement in the conductor.

The invention is primarily intended for use with, and its advantages become particularly apparent in connection with, a high-voltage cable built up of an inner core having a plurality of strand parts, an inner semiconducting layer, an insulating layer surrounding this and an outer semiconducting layer surrounding the latter, a cable in particular having a diameter of 20-200 mm and a conducting area of 40-3000 mm^2.

With such cables the application thus constitutes preferred embodiments of the invention.

In a preferred embodiment of the invention the resilient bodies are arranged beside and close to respective cable lead-throughs.

In a preferred version of this embodiment each resilient body is arranged to abut onto two adjacent cable lead-throughs, thereby reducing the number of bodies required.

The advantages of the invention are of particular interest when the slots are provided with alternately wide and narrow parts. Such a design ensures stable fixing of the cable and enables optimum utilization of the space for the stator laminations. In this case it is advantageous for the narrow parts to be formed by one wall of the slot protruding in towards the slot. The space at the other slot wall may then be wider and provide space for the resilient bodies. It is also advantageous for the other slot wall in the corresponding area to be flat and constitute a tangent to adjacent wide parts.

The bodies are suitably of silicon rubber. This is suitable in view of its elasticity and also because it lacks process oil which might otherwise diffuse out and attack the outer semiconducting layer of the cable.

In yet another preferred embodiment of the invention, each resilient body has a convex profile in axial section. This offers less friction resistance when the bodies are inserted into the slot.

In yet another embodiment the bodies are designed as support members arranged around the cable and surrounding it.

The support members facilitate insertion of the cable into the slot when the stator is being wound. The cable is then drawn through these, each support body contributing to centring the cable in the slot as it is being drawn towards the next. The cable is in this case relatively rigid so that it may be guided towards the next support member and may be threaded through it. The rigidity of the cable ensures that there is no risk of it touching the slot walls during insertion.

The risk of the laminations in the wall scratching the sensitive outer surface of the cable, resulting in damage, is therefore eliminated.

In a preferred version of this embodiment the support members are arranged in annular recesses in the slot wall. When the cable expands during operation, therefore, it will compress the support element in this recess and will reach the slot walls between the recesses.

Each support member is suitably in the form of a rubber ring and it is advantageous for these to be glued into the slot wall.

The above and other advantageous embodiments of the machine according to the invention are defined in the sub-claims to claim 1.

In a second aspect of the invention the purpose is achieved by giving a method of the type described in the preamble to claim 18 the special features defined in the characterizing part of this claim.

Inserting resilient bodies in this way produces a machine with supports for the cable lead-throughs in the slots so that vibration damage is avoided.

In a preferred embodiment of the method the bodies are inserted after the stator has been wound, in a space formed between the adjacent cable lead-through and the slot wall.

Thanks to the bodies being inserted after the cable is in place they do not constitute any obstruction when the stator is being wound.

In a preferred embodiment of the method according to the invention, the bodies are hereby caused to expand after they have been inserted into their places. This enables them to be inserted without being hindered by friction against cable and slot wall during the insertion process.

In different embodiments of the preferred method described above, the body is expanded only through axial compression or by being pre-compressed in this direction upon insertion and then relieved of this pre-compression.

The manner in which these two ways achieve expansion is explained with reference to preferred embodiments of the method.

In one alternative preferred embodiment, each body inserted has a cavity running axially through it and the cable is threaded through after the bodies have been applied. It is thus threaded through these cavities. .

The above and other advantageous embodiments of the method according to the invention are defined in the sub-claims to claim 18.

The invention will be explained in more detail in the following description of preferred embodiments, with reference to the accompanying drawings in which;

Figure 1 shows schematically an end view of a sector of the stator in a machine according to the invention,

Figure 2 shows a cross-section through a cable used in the machine according to the invention,

Figure 3 shows a radial partial section through a stator slot according to the invention,

Figure 4 shows an extracted perspective view of details in Figure 3,

Figure 5 shows a perspective view of a detail according to the invention,

Figure 6 shows a circle section through a detail according to the invention,

Figures 7-9 show sections taken along the line VII-VII in Figure 3, illustrating a first embodiment of the method according to the invention,

Figure 10 is an axial section through an auxiliary means according to a second embodiment of the method according to the invention,

Figure 11 is a section taken along the line VII-VII in Figure 3, illustrating a second embodiment of the method according to the invention,

Figure 12 is a section like that in Figure 11, illustrating a third embodiment of the method according to the invention,

Figures 13-18 are axial sections through details in Figure 8 according to two alternative embodiments of the method according to the invention,

Figure 19 is a basic diagram showing the cable arranged in the stator, according to one alternative embodiment,

Figure 20 is a detail of Figure 19 when the machine is at rest,

Figure 21 is a detail corresponding to Figure 20 but when the machine is in operation,

Figures 22 and 23 are alternative embodiments of the detail in Figure 20.

In the axial view shown schematically in Figure 1 through a sector of the stator 1 of the machine, its rotor is designated 2. The stator is composed in conventional manner of a laminated core of sheet steel. The figure shows a sector of the machine, corresponding to one pole division. From a yoke portion 3 of the core situated radially outermost, a number of teeth 4 extend radially in towards the rotor 2 and are separated by slots 5 in which the stator winding is arranged. The cables 6 in the windings are high-voltage cables which may be of substantially the same type as high-voltage cables used for power distribution, so-called XLPE cables. One difference is that the outer mechanically protective sheath and the metal screen that normally surround such a cable have been eliminated. The cable thus comprises only the conductor, an inner semiconducting layer, an insulating layer and an outer semiconducting layer. The semiconducting layer, sensitive to mechanical damage, is thus exposed on the surface of the cable.

In the drawing the cables 6 are illustrated schematically, only the conducting central part of the cable lead-through or coil side being filled in. As

can be seen, each slot 5 has varying cross section with alternating wide parts 7 and narrow parts 8. The wide parts 7 are substantially circular and surround cable lead-throughs, and the waist parts between these form narrow parts 8. The waist parts serve to radially position each cable lead-through. The cross section of the slot as a whole also becomes slightly narrower in radial direction inwards. This is because the voltage in the cable lead-throughs is lower the closer they are situated to the radially inner part of the stator. Slimmer cable lead-throughs can therefore be used here, whereas increasingly coarser cable lead-throughs are required further out. In the example illustrated cables of three different dimensions are used, arranged in three correspondingly dimensioned sections 9. 10, 11 of the slots 5.

Figure 2 shows a cross-sectional view of a high-voltage cable 6 according to the present invention. The high-voltage cable 6 comprises a number of strand parts 31 made of copper (Cu), for instance, and having circular cross section. These strand parts 31 are arranged in the middle of the high-voltage cable 6. Around the strand parts 31 is a first semiconducting layer 32. Around the first semiconducting layer 32 is an insulating layer 33, e.g. XLPE insulation. Around the insulating layer 33 is a second semiconducting layer 34. The concept "high-voltage cable" in the present application thus need not include the metal screen and the outer protective sheath that normally surround such a cable for power distribution.

Figure 3 illustrates on a larger scale a slot 5 with alternating narrow parts 7 and wide parts 8 as in Figure 1, but differing somewhat from those shown in Figure 5 in that the narrow parts 7 are formed by an

indentation in the slot wall on only one side of each narrow part 7. A space which can be described as roughly triangular is formed in the section of the opposite slot wall facing the indentation, and in each such space a number of resilient bodies 12, 13, 14 are arranged. Each resilient body is in pressure contact with the slot wall and also with two adjacent cable lead-throughs 6, the latter thus being clamped by the resilient bodies. The resilient bodies are made of a type of rubber that does not contain remnants of process oil, e.g. silicon rubber.

The perspective view in Figure 4 shows two cable lead-throughs and how the resilient bodies 13a, 13b, etc. are arranged axially along the cable lead-throughs along the whole length of the stator.

The bodies 13a, 13b shown in Figure 4 are in the form of circular cylinders but may advantageously be somewhat cambered so that they acquire a barrel-like shape as illustrated in Figure 5.

The cross-section of the bodies perpendicular to the axial direction need not be circular but, as illustrated in Figure 6, have a shape more suited to the available space.

Figures 7-12, all of which are sections taken along the line VII-VII in Figure 3, reveal two alternative methods of inserting the resilient bodies.

Figures 7-9 show three stages of the insertion according to a first alternative. A rod 15 with a plate 16 at one end is inserted in the "triangular" space between two cable lead-throughs 6 (only one of which is visible in the figures) and the stack of

laminations in the stator 1. The first body 13a is threaded onto the other end of the rod. Each body has a cavity 17 running axially through it, substantially corresponding to the diameter of the rod 15. The first body 13a is inserted into the slot 5, sliding along the rod 15. When the body reaches the plate 16 it is prevented from moving further and assumes the position shown in Figure 7. The cross-sectional shape of the body is such that it can be freely inserted through the slot in this way but with little clearance.

Figure 8 shows how an axial pressure A is applied to the body 13a when it is in place, thereby compressing the body axially so that it simultaneously expands in transverse direction. This expansion and the unloaded dimensions of the body are selected such that in this position it will be in contact with both the slot wall and the two cable lead-throughs. In this position a locking device 18a is applied which is pushed axially along the rod to abutment with the body 13a, thereby locking it in this expanded state. The next body 13b is then pushed axially along the rod until it is in contact with the locking device 18a, after which it is compressed axially and locked in place with a second locking device 18b in the same way as the first body 13a. The following bodies 13c, 13d, etc. are then applied one after the other in corresponding manner until the slot has been filled.

Figures 13 and 14 show a first example of how the locking device 18 may be shaped. The rod 15 here is provided with serrations 19 with inclined surfaces 20 and perpendicular surfaces 21, respectively, in relation to the longitudinal axis of the rod, the inclined surfaces facing the threading end of the rod. The locking device itself is shown in Figure 14 and

consists of a plastic sleeve, e.g. of nylon, having a first part with an inner diameter d_1 corresponding to the outer diameter of the rod, and a second part with an inner diameter d_2 which is slightly larger. In the transition between the two parts a thin, inclined flange 22 is formed leaving an opening with a diameter d_3 which is smaller than the outer diameter of the rod, suitably corresponding to the diameter at the bottom of the serrations. The flange is sufficiently thin to be able to resilient snap over the serrations 19 when the sleeve 18 is passed over the serrated rod in the direction of the arrow B and which can snap into a groove formed by two serrations and is thus prevented from moving in the opposite direction.

Another example of how the locking device may be designed is shown in Figures 15-18.

Figures 15 and 16 show the rod with screw threading on only two opposite segments 23 and flat on the other two opposite sides 24.

The locking device in Figures 17 and 18 is in the form of a sleeve 18' having internal threading 25 on two opposite segments and a hole diameter down to the bottom of the thread between. This enables the sleeve 18', in a position where its threaded segments 25 are turned 90° in relation to the threaded segment 23 of the rod, to be threaded over the rod. When the sleeve 18' has been moved in this way to its locking position, it is turned to engagement between the threaded segments 23 and 25 and firmly locked in this position. A notch 26 is provided at one end of the sleeve 18'in order to turn it.

The sleeve 18, 18' in the locking devices described above has an axial length to suit the desired distance between the bodies 13a, 13b, etc. and thus also acts as spacer.

An alternative method of inserting the resilient bodies 13 is illustrated in Figures 10-12 showing the various stages for insertion and application of a body 13. A tube 27 is inserted axially into the space between the slot wall and the adjacent cable lead-throughs 6. The tube 27 has a cross-sectional shape to enable its insertion into the space with slight clearance. The tube 27 is provided at its outer end with a funnel-like section 28. This expands to dimensions wider than the available space in the slot and therefore does not reach into the slot upon application of the bodies 13.

A resilient body is inserted in uncompressed state into the funnel-like section 28 and, on passing this section 28, it will be compressed at right angles to the axial direction and thus become somewhat longer. The body 13 is then pressed through the tube to its opposite end, e.g. by a rod 29 with a pressure plate 30 at its end. When the inner end surface of the body 13 has reached the inner opening 31 of the tube 27 the rod 29 is then locked in this position and the tube 27 is pulled out a short distance, i.e. in the direction of the arrow C (Figure 11). The body 13 is prevented by the pressure plate 30 from accompanying the movement of the rod , and will consequently be fed out of the tube 27 when this is withdrawn. It is then free to expand transversely to the axial direction, as can be seen in Figure 11 where the body 13 is partially pressed out.

The tube can be withdrawn sufficiently to allow the whole resilient body 13 to exit from the tube and

expand. In expanded state it presses against both the slot wall and the adjacent cable lead-throughs 6 as shown in Figures 3 and 4. The same procedure is then repeated with the next and following resilient bodies, with the tube drawn further and further out of the slot.

Figure 12, illustrating the same position as Figure 11, shows an alternative method of pressing the resilient bodies through. Here a pressurized fluid, e.g. compressed air, is used instead of the pressure rod 29. When the body 13 has been inserted into its position the outer end of the tube is sealed with a tight lid 32 through which a compressed air conduit 33 communicates with the interior of the tube. When the valve 34 is opened the air forces the body 13 into its position, after which the tube 27 is withdrawn as described above.

To reduce the friction when the bodies 13 are forced through the tube, it may be suitable to lubricate them with talcum or boron nitride, for instance. Alternatively, the inside of the tube may be lubricated.

The method according to any of the alternatives described above has been explained when all resilient bodies in such a space are inserted from the same direction. However, it is also possible to insert about half from one direction and the rest from the other end of the stator.

In an alternative embodiment Figure 19 shows a lead-through of the cable 6 through one of the stator slots 1, the figure showing its axial extension. Support members 112 for the cable are arranged at regular

intervals. The distance between support members is chosen so that vibrations, particularly in the frequency range 100 Hz, are suppressed, resulting in about 2 - 4 support elements per metre of cable.

Figure 20 shows such a support member 112 on an enlarged scale when the machine is at rest. The support member 112 is deformable, suitably resilient, and is preferably made of rubber. In the present application "rubber" includes other materials having rubber-like properties. The rubber element 112 is annular and is applied in an annular recess 113, about 5 mm deep, in the wall of the slot 5. The rubber ring 112 is glued to the bottom of the recess 113. When the machine is at rest and during winding of the cable, the rubber ring has an inner diameter approximately corresponding to the cold diameter of the cable 6, or somewhat larger. The outer diameter corresponds to the diameter of the recess 113 and its length is about 10-15 mm.

When the stator is wound the cable 6 is inserted axially into a slot. The slot has a width greater than the diameter of the cable to permit expansion thereof when it becomes hot during operation. The cable is drawn through the aperture in each rubber ring 112 so that it is centred in the slot. The cable is thus prevented from coming into direct contact with the walls of the slot 5 and there is therefore no risk of the laminations damaging the outer sheath of the cable. A high-voltage cable of the type under consideration is relatively rigid so that it is guided in its central position as it passes from one rubber ring to the next. The cable is lubricated during winding to facilitate its passage through the rubber rings. The rubber rings may also be slightly bevelled at the side of the hole

where the cable enters, or the tip of the cable may be slightly bevelled so that it is slightly conical.

When the machine is in operation the cable 6 will expand due to heat in the copper core. The rubber ring is then compressed as shown in Figure 5. The width of the slot 5 is selected so that during operation the cable will expand until it abuts lightly onthe slot wall. The rubber ring 112 is then compressed in the recess 113, which has sufficient depth to permit this. The inner diameter of the rubber ring 112 will then be approximately the same as the slot width. In this position the cable is firmly clamped at 2 - 4 places per metre, but lies relatively loosely against the slot wall in between.

The rubber element 112 in Figure 20 need not necessarily have triangular cross-section. Figures 20 and 23 show two alternative embodiments of the rubber element. In Figure 22 the element 112a has an equilateral triangular part formed by two inclined surfaces 114 facing the cable 6 so that the contact is at points (along a circular line) at the tip 115. The inclined surfaces 114 facilitate insertion of the cable. In Figure 23 the element 112b has a correspondingly triangular part in cross-section but with only one inclined surface 114b facing the direction from which the cable is inserted. Contact is then obtained at the tip 115b on the one side of the element. During operation, however, as a result of compression of the element, contact will occur with a surface having a certain lateral extension also. Amongst other alternative shapes of the cross- section of the element, this has a trapezium-shaped part with the shorter side facing the cable, or is shaped with a convex surface towards the cable.

The rubber rings 112 according to the invention enable the cable to be drawn easily during winding, without risk of damage to the outer semiconducting layer of the cable, and avoid damaging vibrations in the cable during operation.

CLAIMS

1. A rotating electric machine comprising a stator with windings (6) drawn through slots (5) in the stator (1), characterized in that at least one winding (6) comprises an insulation system comprising at least two semiconducting layers (32, 34), each layer essentially constituting an equipotential surface, and also including solid insulation (33) between these layers (32, 34), and in that a plurality of resiliently deformable bodies (13, 112) are arranged along at least one cable lead-through of the winding, said bodies (13, 112) being arranged to abut with pressure onto the cable lead-through.

2. A machine as claimed in claim 1, wherein at least one of said layers (32, 34) has essentially the same coefficient of thermal expansion as the solid insulation (33).

3. A machine as claimed in claim 1 or claim 2, wherein the cable (6) is of a type comprising a core with a plurality of strand parts (31).

4. A machine as claimed in claims 1-3, wherein the cable (6) has a diameter within the range of 20-200 mm and a conducting area within the range of 40-3000 mm^2.

5. A machine as claimed in any of claims 1-4, wherein each body is arranged beside and close to respective cable lead-throughs (6).

6. A machine as claimed in claim 5, wherein each resilient body is arranged to abut onto two adjacent cable lead-throughs (6) with pressure.

7. A machine as claimed in claims 5-6, wherein said slots (5) have in radial direction alternately narrow parts (8) and wide parts (7).

8. A machine as claimed in claim 7, wherein in an arbitrary radial section through the slot, one of the opposing walls of the slot in a narrow part (8) has a profile with an indentation towards the middle of the slot, said bodies (13) being arranged to abut onto the section of the opposite wall situated opposite said indentation.

9. A machine as claimed in claim 8, wherein the section of the wall opposite said indentation is flat and consists of a common tangent to the adjacent wide parts (8) of the slot.

10. A machine as claimed in any of claims 5-9, wherein each body (13') in an axial section has a substantially convex profile.

11. A machine as claimed in any of claims 1-8, wherein each body (13) in radial section has a circular profile.

12. A machine as claimed in any of claims 1-9, wherein said body (13) is preferably made of silicon rubber.

13. A machine as claimed in any of claims 5-12, wherein said body (13) is hollow, preferably having a cavity through it, running parallel to adjacent cable lead-throughs.

14. A machine as claimed in any of claims 1-4, wherein the deformable bodies (112) are support members arranged around the cable (6), surrounding it and abutting onto the wall of the slot (5).

15. A machine as claimed in claim 14, wherein each support member (112) is arranged in an annular recess (113) in the slot wall.

16. A machine as claimed in claim 15, wherein each support member (112) is in the form of an annular rubber element and is glued to the wall of the slot (5).

17. A machine as claimed in claim 16, wherein said rubber elements (112) are arranged spaced 20-60 cm apart and, in undeformed state, have an inner diameter that corresponds substantially to the outer diameter of the cable (6) when the machine is at rest.

18. A method when manufacturing a rotating electric machine of the type claimed in claim 1, characterized in that the stator is wound with high-voltage cable and that a plurality of resilient bodies are inserted axially in at least one of the slots.

19. A method as claimed in claim 18, wherein the bodies are inserted after the stator has been wound and inserted in a space formed between an adjacent cable lead-through and one of the slot walls.

20. A method as claimed in claim 19, wherein each body after being inserted into its position in the slot

is caused to expand transversely to the axial direction.

21. A method as claimed in claim 13, wherein the body is resilient and is caused to expand by being compressed axially.

22. A method as claimed in claim 21, wherein a rod provided with an end stop is inserted axially in said space and each body is provided with an axial hole, a first body being threaded onto the rod and inserted into the slot until it reaches the end stop, after which axial pressure is applied to the body until it has expanded to abut onto both the slot wall and the adjacent cable lead-through(s), after which the body is locked in this position and the next body is inserted in the same way until it is impeded by the first body, after which the second body is also compressed and locked, and that thereafter additional bodies are inserted in the same way.

23. A method as claimed in claim 20, wherein the body is resilient and is inserted perpendicular to the axial direction in compressed state and is caused to expand by releasing the compression.

24. A method as claimed in claim 23, wherein a tube is inserted in said space, said tube having an inner cross section with smaller cross-sectional area than the bodies in unloaded state, a first body being compressed and inserted into the tube, after which the tube is withdrawn a short distance while the body is being held in place and is thus permitted to expand at right angles to the axial direction, after which other bodies are inserted in the same manner.

25. A method as claimed in claim 24, wherein the bodies are inserted using mechanical aids.

26. A method as claimed in claim 24, wherein the bodies are inserted with the aid of pressure fluid.

27. A method as claimed in any of claims 24-6, wherein the tube has a funnel-like section at its outer end.

28. A method as claimed in claim 18, wherein the bodies have a cavity running axially through them and wherein the bodies are arranged in line with each other, after which high-voltage cable is wound by inserting it through the bodies serving as support members.

29. A method as claimed in claim 28, wherein a number of annular recesses are made in the stator slot, situated axially in line with each other and wherein one of said support members is applied in each recess.

30. A method as claimed in claim 29, wherein each support member is inserted as an annular rubber element and is glued into the slot wall.

31. A method as claimed in claim 30, wherein the rubber elements are applied with a distance between them of 20-60 cm and each rubber element has an inner diameter in undeformed state that substantially corresponds to the outer diameter of the cable when the machine is at rest.

32. A method as claimed in any of claims 29-31, wherein lubricant is used when the cable is inserted through the support members.

Fig. 1

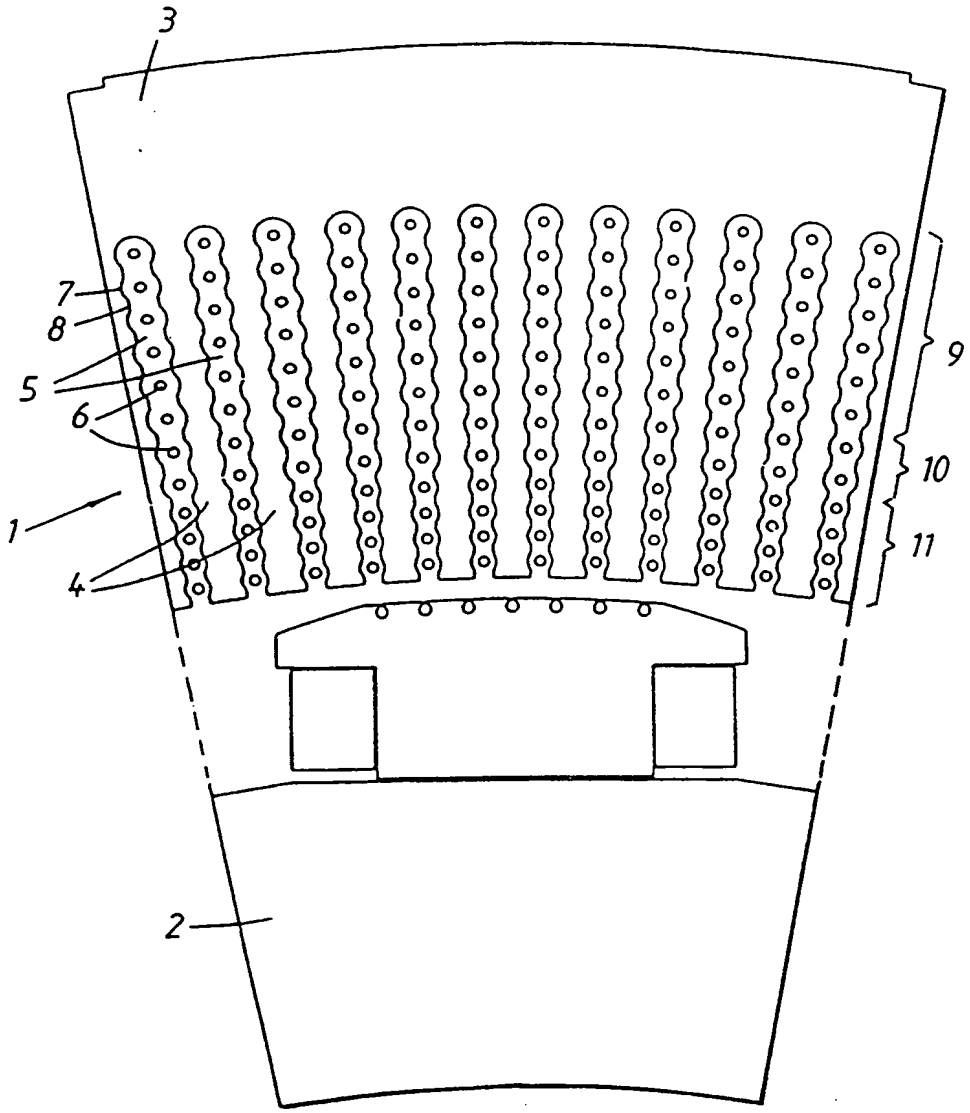

Fig. 2

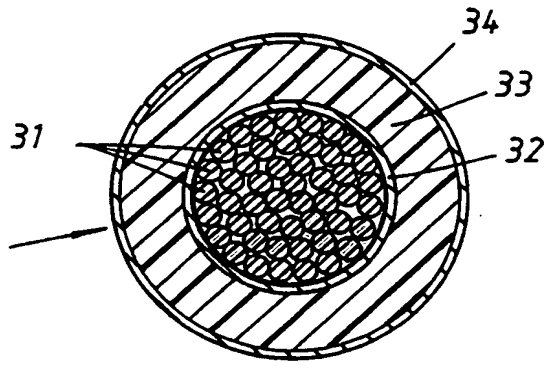

Fig. 3

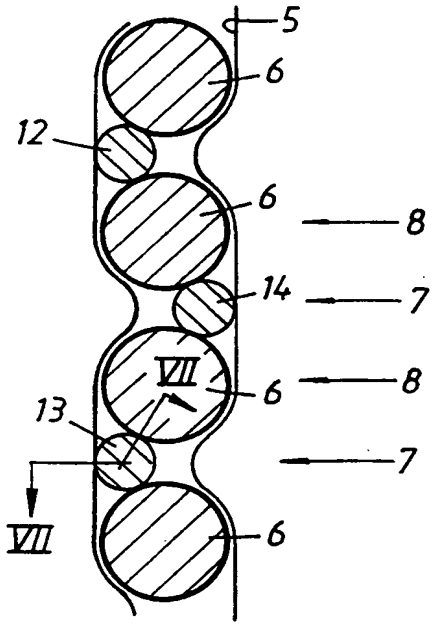

Fig. 4

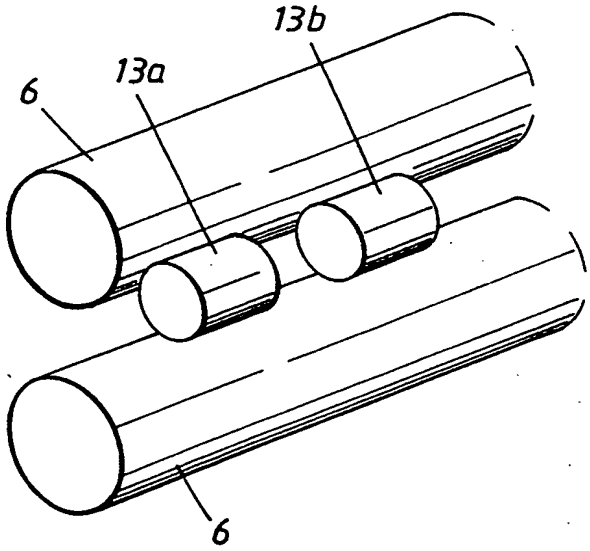

Fig. 5

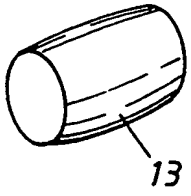

Fig. 6

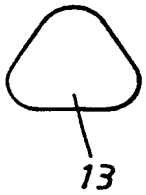

Fig. 7

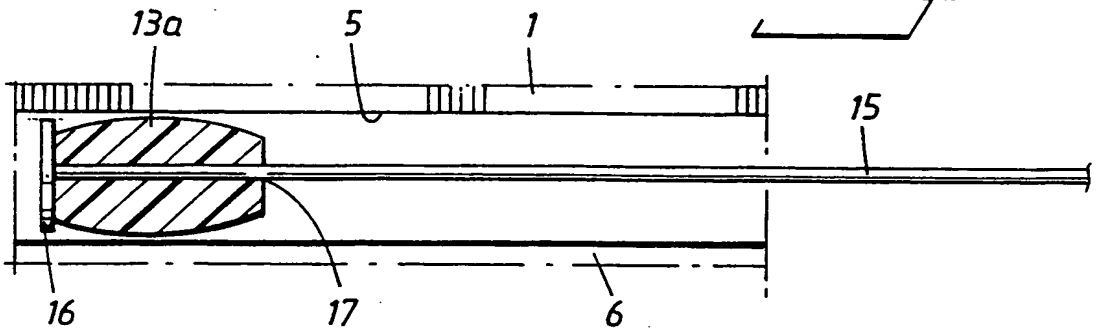

Fig. 8

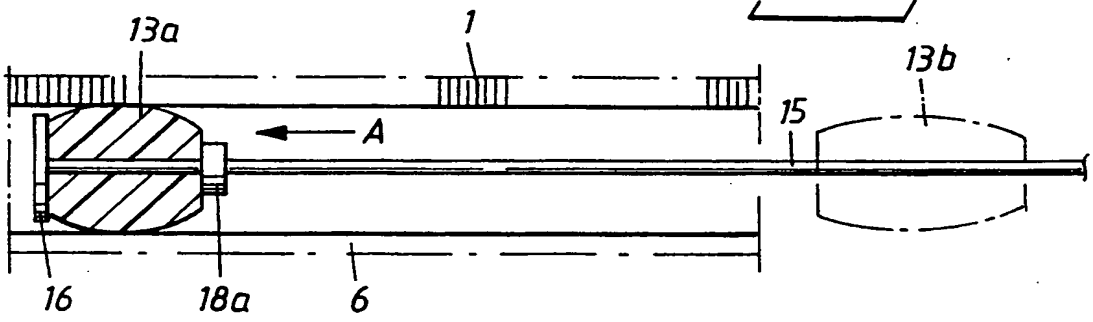

Fig. 9

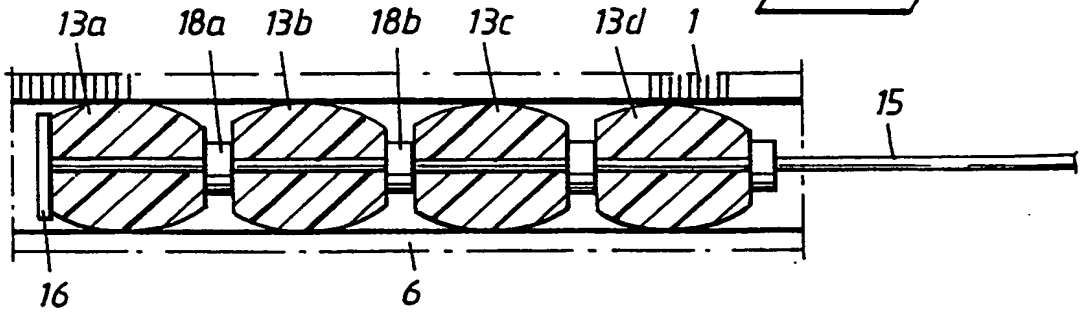

Fig.10

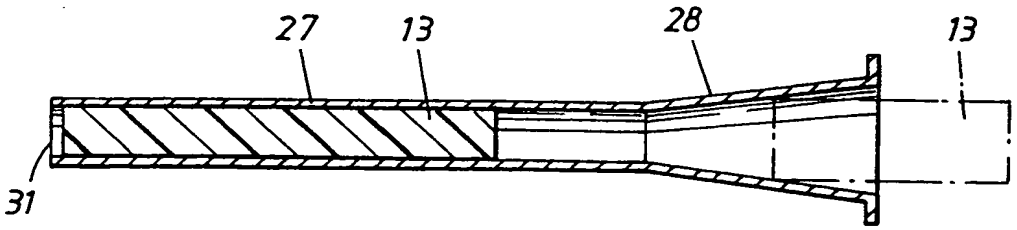

Fig.11

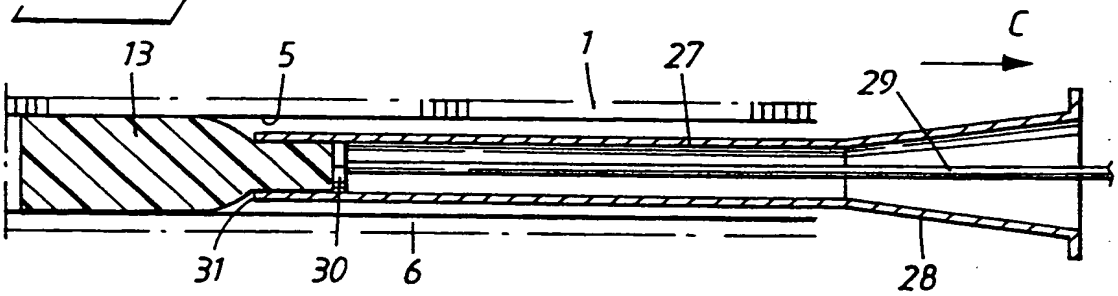

Fig.12

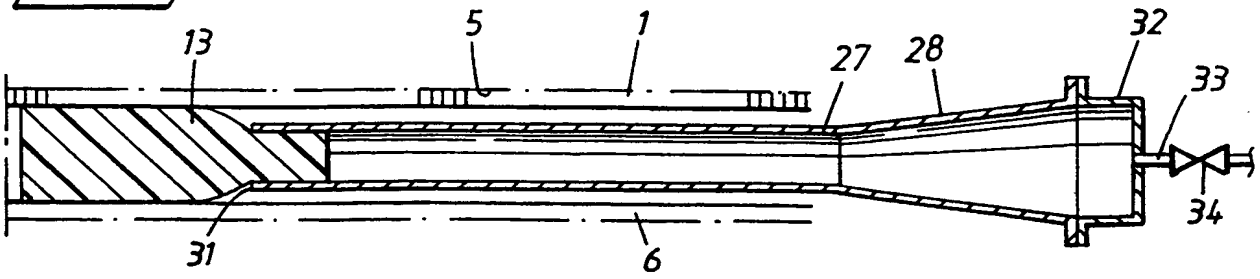

Fig.13

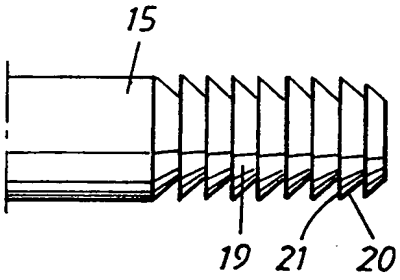

Fig.14

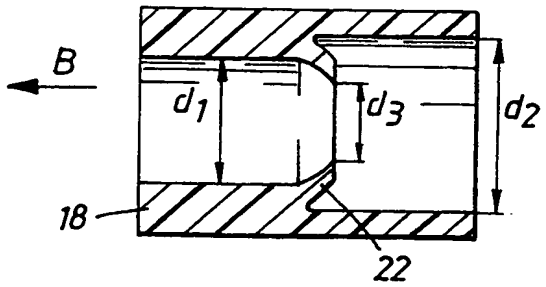

Fig.15

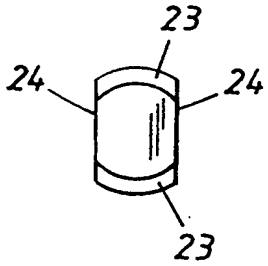

Fig.16

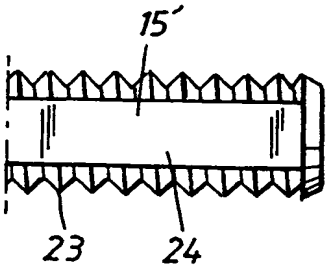

Fig.17

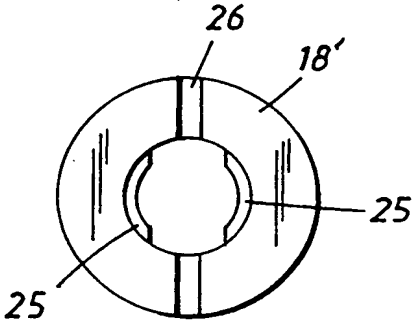

Fig.18

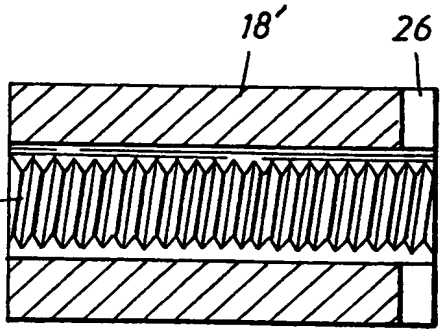

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Fig. 19

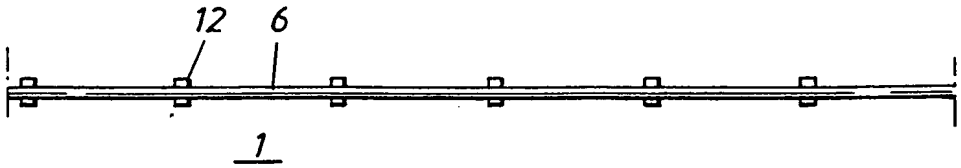


Fig. 20

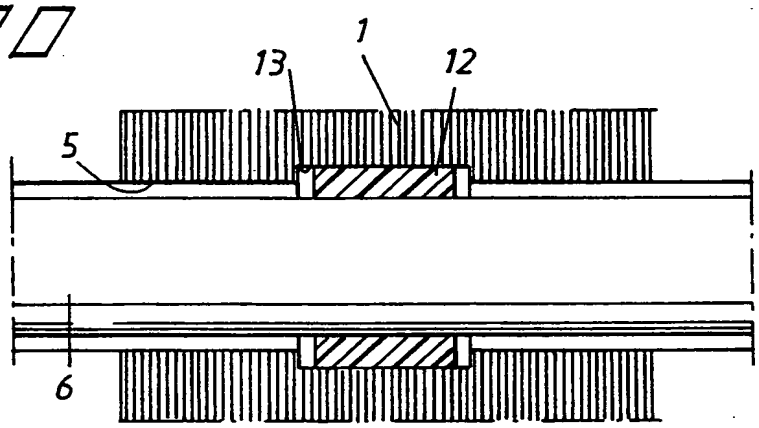


Fig. 21

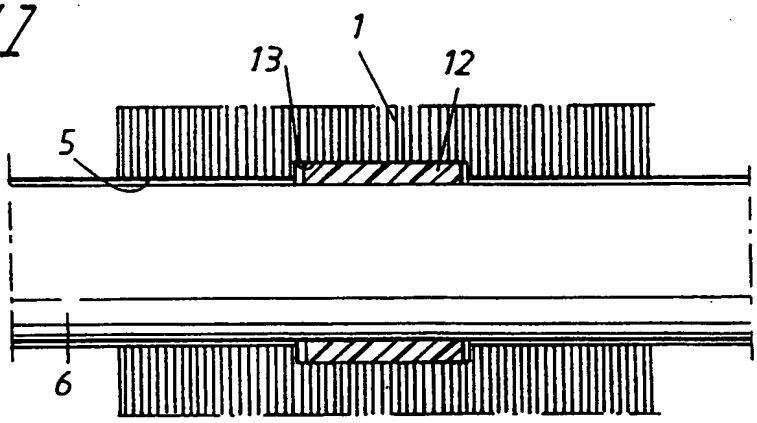


Fig. 2a

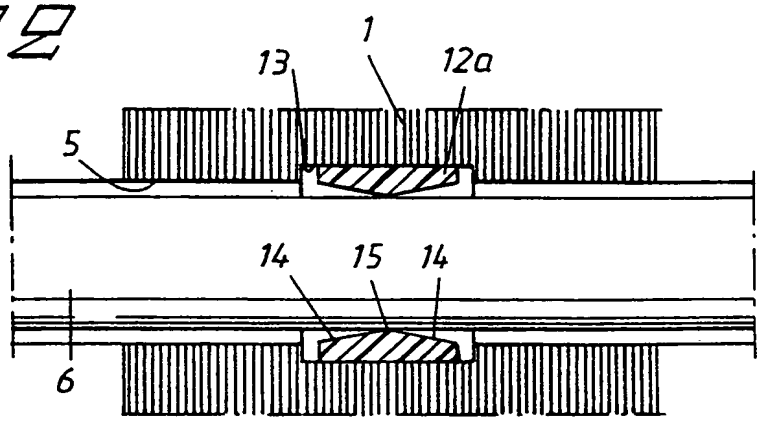
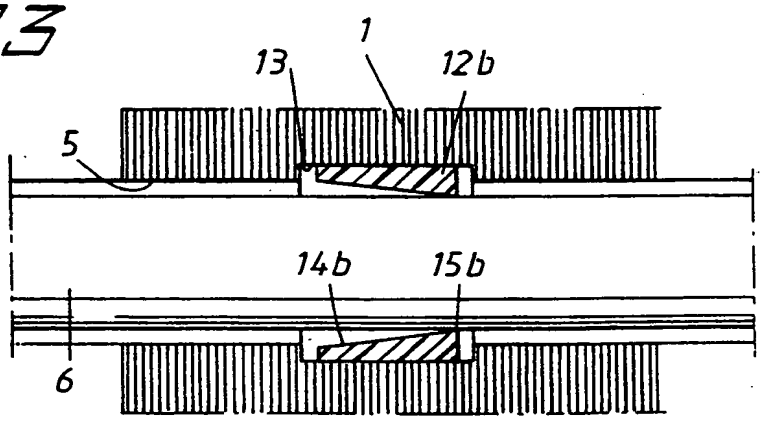


Fig. 2b



INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 97/00907

A. CLASSIFICATION OF SUBJECT MATTER

IPC6: H02K 3/40, H02K 3/48, H02K 15/08
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC6: H02K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

WPI

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 5036165 A1 (R.K. ELTONE ET AL.), 30 July 1991 (30.07.91), column 1, line 16 - line 60; column 2, line 26 - line 57, figure 1, abstract	1,3-5,7-8, 12,18-21,23
A		9-11,13-17
	--	
Y	US 3158770 A1 (A.D. COGGESHALL ET AL.), 24 November 1964 (24.11.64), column 1, line 70 - line 72; column 2, line 1 - line 7; column 2, line 40 - line 45, figures 1,2, column 2, line 67 - line 72	1,3-5,7-8,12
A		18,19
	--	

[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" erlier document but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
9 October 1997	15 -10- 1997
Name and mailing address of the ISA/ Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Authorized officer Håkan Sandh Telephone No. +46 8 782 25 00

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 97/00907

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	FR 2594271 A1 (SOCIETE DE PARIS ET DU RHONE), 14 August 1987 (14.08.87), figures 1,2, abstract	8
Y	US 4008409 A1 (R.G. RHUDY ET AL.), 15 February 1977 (15.02.77), column 3, line 16 - line 32; column 5, line 6 - line 33, figures 2-3	12
Y	SU 955369 A ((GIDR) SCI SECT GIDROPROEKT RES INST), 30 August 1982 (30.08.82), figures 1,2, abstract	7
A	EP 0571155 A1 (MITSUBA ELECTRIC MFG. CO., LTD.), 24 November 1993 (24.11.93), abstract	2
A	FR 2556146 A1 (SOCIETE DE PARIS ET DU RHONE), 7 June 1985 (07.06.85), page 3, line 17 - line 23, figures 1-4, abstract	1,5,6,11
Y		18-21,23
A	US 4347454 A1 (K. GELLERT ET AL.), 31 August 1982 (31.08.82), column 1, line 55 - line 58; column 2, line 1 - line 2, the figure	14-17,28-32
Y	US 5325008 A (J.J. GRANT), 28 June 1994 (28.06.94), column 1, line 7 - line 11; column 2, line 10 - line 21; column 2, line 51 - line 57, figures 1 and 6, column 3, line 31 - line 34; column 4, line 61 - line 63; column 5, line 17 - line 19	20-21,23

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 97/00907

Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reas ns:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

I. Claims 1-17 describing a statorwinding and elastically deformable bodies arranged along a cabling of the winding.

II. Claims 18-32 describing elastically deformable bodies arranged axially in at least one of the statorslots.

1. ☒ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this internati nal search report is restricted to the invention first mentioned in the laims; it is covered by claims Nos.:

Remark n Protest

☐ The additi nal search fees were accompanied by the applicant's protest.

☒ N protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

Information on patent family members

01/09/97

International application No.
PCT/SE 97/00907

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 5036165 A1	30/07/91	US 5066881 A	19/11/91
		US 5067046 A	19/11/91
		CA 1245270 A	22/11/88
		US 4853565 A	01/08/89
US 3158770 A1	24/11/64	NONE	
FR 2594271 A1	14/08/87	NONE	
US 4008409 A1	15/02/77	BR 7602220 A	05/10/76
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EP 0571155 A1	24/11/93	CA 2096500 A	19/11/93
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		US 5446324 A	29/08/95
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		DE 2836229 A,C	21/02/80
US 5325008 A	28/06/94	CA 2103422 A	10/06/94
		EP 0601827 A	15/06/94
		JP 6237549 A	23/08/94